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Potential Performance Criteria for Combat Ration Packs – Texture Profile Analysis

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ABSTRACT

DEF(AUST) specifications for combat ration pack (CRP) food components include functional and performance criteria to ensure that components that are procured are suitable for their intended purpose. Texture profile analysis (TPA) and water activity (a_w) data have been reviewed to assist in the establishment of performance criteria for CRP food components. The texture measurements displayed large standard deviations limiting their usefulness as performance indicators. In contrast, the uncertainty associated with the a_w data was very low. It is suggested that a_w be used instead of TPA as a measure of textural quality and stability. An understanding of the correlation between TPA and sensory evaluation data would then be required to establish performance criteria based on TPA.

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Executive Summary

DEF(AUST) specifications for combat ration pack (CRP) food components include functional and performance criteria to ensure that the components procured are suitable for their intended purpose. In addition to sensory requirements, many DEF(AUST) specifications include texture profile analysis (TPA) and water activity (a_w) as 'future requirements', indicating an intention to identify and set performance criteria and add them to the specifications.

The purpose of this report is to review instrumental texture and a_w as measures to assist in the establishment of performance criteria for CRP food components.

In general, the texture measurements examined had high standard deviations. This made it difficult to establish a useful performance indicator based on instrumental texture. Despite the current measurement uncertainty, it is clear that there were some significant changes in texture during storage of canned processed cheddar cheese, puddings and biscuits. Therefore the report proposes ways to reduce the measurement uncertainties of TPA.

The a_w data examined in the preparation of this report had small standard deviations. Where changes in texture correlate with changes in a_w, there may be opportunities to establish performance criteria based on a_w. In addition to being able to be measured to high precision, a_w can be more readily and economically measured.

However the usefulness of a_w measurements in establishing performance criteria would be rely on there being a recognised and measureable relationship between a_w and sensory quality. It is also important to understand the correlation between TPA measurements and sensory evaluation data to determine the instrumental texture at which sensory texture is no longer acceptable. A study designed to elicit this information would be required before performance criteria based on TPA could be established with a high level confidence in their use.

Conclusions

1. TPA measurements have large standard deviations and are not currently suitable for the setting of performance criteria.
2. As some significant changes in texture during storage were observed, efforts should be made to either reduce the uncertainty associated with TPA measurements or establish a suitable surrogate measure. Some approaches that may improve TPA are discussed.

3. Significant changes in texture were observed for golden and chocolate self-saucing puddings and biscuits. It might then be possible to establish performance criteria based on TPA measurements for these food types.
4. Changes in some texture attributes correlated with changes in a_w, the uncertainty associated with measuring a_w is typically small, and the method can be readily and cheaply applied. Using a_w as a surrogate measure of textural quality is thus an attractive proposition.
5. The correlation between TPA measurements and sensory evaluation data has not been investigated, therefore the establishment of TPA criteria that have been validated against sensory texture data not yet possible.

Recommendations

1. Where there is evidence that TPA measurements may be useful as performance criteria, it would be useful to investigate means to reduce the uncertainty associated with the TPA measurements, implement improvements and establish suitable criteria. Efforts to establish texture-based performance criteria should focus initially on golden and chocolate self-saucing puddings and biscuits.
2. Investigate the possibility of using a_w instead of TPA as a measure of textural quality and shelf life performance. Efforts to establish performance criteria based on a_w as a surrogate for TPA measurements should focus initially on biscuits.
3. Determine the correlation between TPA measurements and sensory evaluation data, including relevant attributes and the range of TPA values at which sensory texture is not acceptable.

Contents

Acronyms

AOAC	Association of Official Analytical Chemists
a_w	water activity
CRP	Combat Ration Packs
DEF(AUST)	Australian Defence Standard
DMO	Defence Materiel Organisation
DSTO	Defence Science and Technology Organisation
TPA	texture profile analysis

1. Background

Texture is a major factor in our enjoyment of food. However, processing, packaging and storage can all affect the texture of food.

The perception of food texture varies from food to food, person to person, and with culture and age. The complexity of food texture perception has been studied for many decades. Szczesniak and Kahn (1971) reported that the serving size also appears to influence the acceptance of textural characteristics. Hutchings et al. (2009) examined the variation in the natural bite weight, volume and length for different food bars, and found that bite size is controlled by bite length, not weight nor volume. Only about 40% of food was identified correctly when food texture and colour were concealed (Schiffman, 1977; Schiffman et al., 1978). Also, the response of neurons to the texture of food in the mouth, together with taste and other inputs, influences food intake (Rolls, et al., 2003a, Rolls, 2003b). Thus, food texture characterisation is not only important for product development but also essential in order to provide and maintain consistent and acceptable product quality for consumers.

Food texture can be characterised by both sensory and instrumental methods. Sensory evaluation provides a measure of perceived quality; however, it is expensive, time-consuming and can be prone to high variability when carried out over long time periods (Kilcast and Subramaniam, 2000; Kilcast, 2004; deMan and Stanley, 1984; Peleg, 2006). Consequently, instrumental techniques have been developed to measure food properties that relate to sensory attributes. They are preferred over sensory evaluations for both commercial and research applications due to convenience of use, wide availability and because they are less expensive than sensory panels (Lu and Abbott, 2004). The perception of texture is, however, complex and it must be recognised that instrumental methods do not capture the subtleties of the human senses.

DEF(AUST) specifications for combat ration pack (CRP) food include functional and performance criteria to ensure that food items procured are suitable for their intended purpose. In addition to sensory requirements, many specifications note instrumental texture as a 'future requirement', indicating the intention to add one or more instrumental measures of texture once criteria have been suitably identified and set.

Water activity (a_w) has an important effect on the stability of food, including as a control on the growth of microorganisms and the rate of chemical reactions. Therefore, the measurement of a_w is used widely in food research and development, quality control and production. Examples include the use of a_w as an indicator of microbial stability in cake and the water migration in waffles (Pedak, 2009). DEF(AUST) specifications for many CRP food components include a_w performance criteria.

This report reviews instrumental texture and a_w data and suggests ways in which performance criteria for textural attributes of CRP food components may be established.

2. Materials and Methods

2.1 Storage condition

Samples of CRP components were placed on storage as described in Table 1. Profiles were developed to provide real time and accelerated shelf life testing data for a broad range of quality measures; rather than being focused solely on detecting and monitoring changes in textural properties.

Table 1 Storage profile for CRP food items.

Storage profile	Storage time	Storage temperature
1	Initials	Initial
2	2 weeks	50 °C
3	4 weeks	50 °C
4	6 weeks	50 °C
5	8 weeks	1 °C
6	8 weeks	50 °C
7	10 weeks	50 °C
8	12 weeks	50 °C
9	3 months	40 °C
10	6 months	1 °C
11	6 months	30 °C
12	6 months	40 °C
13	9 months	40 °C
14	12 months	1 °C
15	12 months	20 °C
16	12 months	30 °C
17	12 months	40 °C
18	18 months	30 °C
19	24 months	1 °C
20	24 months	20 °C
21	24 months	30 °C
22	36 months	20 °C
23	48 months	1 °C
24	48 months	20 °C

Note: Control samples, i.e. 'Initials,' were analysed to capture the original quality of the product and also provide a benchmark for determining changes during storage.

2.2 Data Collection

Our evaluation was based on in-house instrumental texture data for CRP built in 2009/10. Data was available for the following components:

- Cereal products: cream cracker biscuit, plain sweet biscuit, butter biscuit, crispbread biscuit, apricot muesli bar, tropical muesli bar, forest fruits muesli bar, chocolate pudding, golden pudding and fruit pudding.
- Dairy products: canned processed cheddar cheese.

It is noted that:

- No initial texture measurements were performed on chocolate pudding, fruit pudding and muesli bars (Profile 1, Table 1).
- Three packages of each component were analysed for each storage profile.
- The number of analyses was based on the unit content in the package, except where the contents were broken or damaged.
  - For samples having one unit per package, such as muesli bar, pudding or cheese: one measurement was taken per package; three readings were obtained for each storage profile.
  - For samples having more than one unit per pack such as biscuits (4 per pack): more than one measurement was performed; broken units were excluded. In some cases, up to twelve measurements were taken per storage profile.
  - Variation in the number of units per package led to variation in the amount of data collected (measurements) across the storage profiles.
- The moisture content of these samples was not determined during storage.
- Water activity was determined at all storage points and is used in this report to determine the relationship with changes in texture. Triplicate analyses (n=3) were performed, however, in some cases, only 1 or 2 data points were obtained.

2.3 Texture analysis

A texture analyser, TA Plus, Lloyd Materials Testing, West Sussex, UK, was used for texture analysis. The parameters were set up with: 100 N load cell, 0.005 kgf trigger and 100 mm/min crosshead speed.

- A snap test was performed for all biscuits and muesli bars, using a 'three point bend rig' to obtain: a) break strength and b) deformation data.
- A compression test was conducted for cheese and puddings, using a conical probe with 75% compression, to obtain a texture profile analysis (TPA). The TPA measurements used in this report are: a) cohesiveness, b) springiness index, c) gumminess and d) stiffness.

2.4 Water activity analysis

Water activity was analysed in triplicate for each profile, using a Dew Point Instrument, in-house method based on AOAC (2007) 978.18C.

2.5 Data analysis

Data was plotted using Microsoft Excel. Student's t-test was used to compare the difference between pre- and post-storage data, including:

- Changes during storage at 1, 20, 30, 40 and 50 °C.
- Changes from initial to the first time point of storage at 1, 20, 30, 40 and 50 °C.
- Changes from initial to the last time point of storage at 1, 20, 30, 40 and 50 °C.

3. Results and Discussion

3.1 Canned cheddar cheese

Canned cheddar cheese had a high fat content, and a firm and smooth texture. The effects of storage on texture are summarised in Table 2 and shown in Figure 1.

Table 2 Texture changes of canned processed cheddar cheese stored at 1, 20, 30, 40 and 50 °C.

Texture attribute/temperature	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
During storage (first vs last storage point)					
Cohesiveness					
Springiness					
Gumminess					
Stiffness					
Initial vs first storage point					
Cohesiveness					
Springiness					
Gumminess					
Stiffness					
Initial vs last storage point					
Cohesiveness					
Springiness					
Gumminess					
Stiffness					

Note:

		Highly significant increase/decrease (p<0.001)
		Significant increase/decrease (p<0.05)
		No significant difference (p>0.05)

Changes during storage (first point versus last point) do not take account of the initial values. During storage at low temperatures (1 and 20 °C) the stiffness did not change but

other texture attributes were significantly affected. At 30 °C there were highly significant changes in all texture attributes, except springiness, which may be masked by the large standard variation in the data for the last two storage points (0.35±0.09 and 0.41±0.19 respectively). Gumminess also increased at 40 °C and stiffness at 40 °C and 50 °C.

TPA generates four measures of texture from a single compression, however when plotted against time the goodness of fit for those measures varied greatly (Figure 1). During storage at 30 °C cohesiveness, springiness and gumminess trended downwards whereas stiffness increased. These patterns are similar to those reported by Szczesniak (1997) who observed increases in firmness and fracturability and a decrease in springiness for cheese samples.

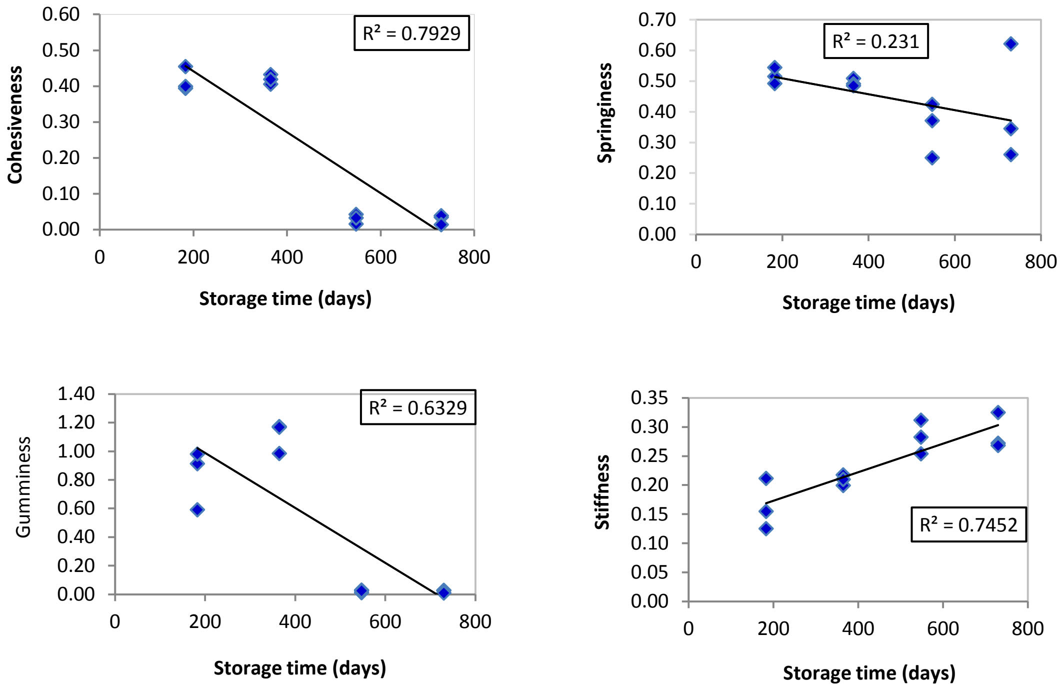

Figure 1 TPA of canned processed cheddar cheese stored at 30 ℃ for 730 days.

The differences between initial values and the first storage point were significant for most attributes at most temperatures, becoming more significant over time (last storage point). This included the changes observed for samples stored at 1°C, suggesting that these samples did not serve as good controls for initial conditions.

Canned processed cheddar cheese is not a commonly available product and a search of the literature did not reveal any directly relevant texture information. However, Syed et al. (2003) evaluated 18 samples of processed cheddar cheese following storage at 10, 20 and 45 °C for 3 months. Their results indicated significant differences in taste, texture, odour, colour and overall acceptability of samples for 3 months at 45 °C compared to samples stored at 10 °C and 20 °C for the same period of time.

The changes that we observed were generally logical, for example when stiffness increased, cohesiveness decreased. However, large standard deviations (e.g. cohesiveness 0.46±0.16; stiffness 0.11±0.04) were common and may have masked changes and trends in textural changes.

Naturally, canned processed cheddar cheese varies in texture due to air pockets and irregular concave surfaces formed in the can during manufacturing. In addition, sample handling, instrumental noise and environmental factors would have contributed to the measurement uncertainty. The sources of uncertainty need to be identified and controlled if texture is to be a reliable measure of product performance during storage. Increasing the number of replicates would reduce the standard deviation, but increased the analysis time and therefore costs.

The a_w of canned processed cheddar cheese changed significantly during storage, both in comparison to the initial values and within the storage period (Table 3 and Figure 2).

Table 3 Changes in a_w of canned processed cheddar cheese stored at 1, 20, 30, 40 and 50 °C.

Water activity/storage conditions	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
During storage (first vs last point)					
Initial vs first storage point					
Initial vs last storage point					

Note:

		Highly significant increase/decrease (p<0.001)
		Significant increase/decrease (p<0.05)
		No significant difference (p>0.05)

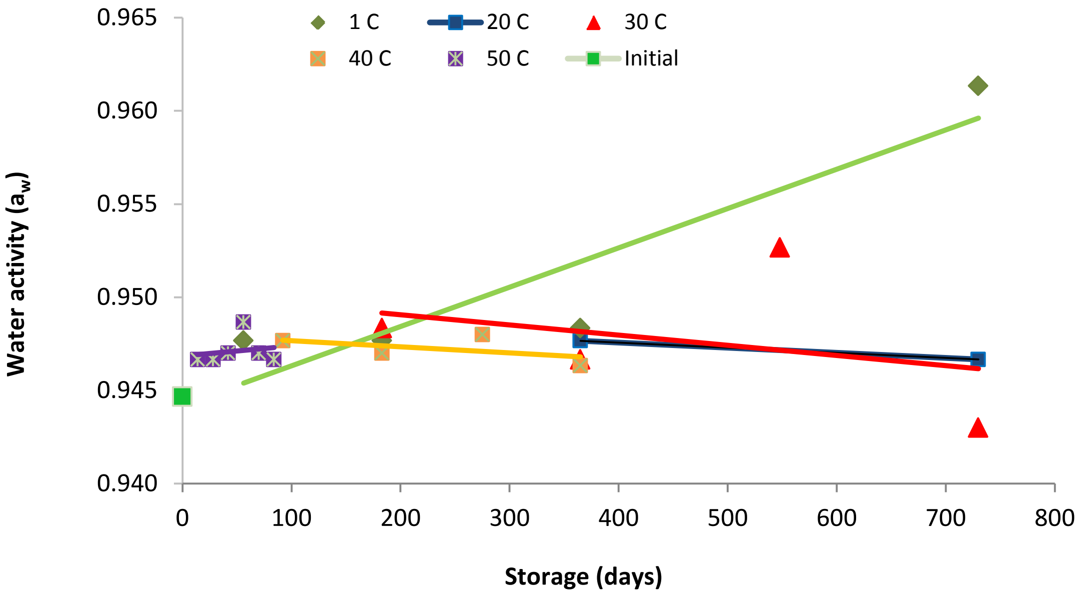

Figure 2 Water activity of canned cheddar cheese stored at 1, 20, 30, 40 and 50 °C

There were significant increases in a_w from the initial to the first storage points for samples stored at 1, 20, 30 and 40 °C. During storage significant changes were observed for samples stored at 1°C and 30 °C. The magnitude of the changes was small, less than 0.02 a_w units. In contrast to the texture data, a_w data was very precise for all storage profiles, e.g. 0.945 ± 0.001. No evidence of a relationship between a_w and texture changes of canned processed cheddar cheese was, however, observed (Figure 3).

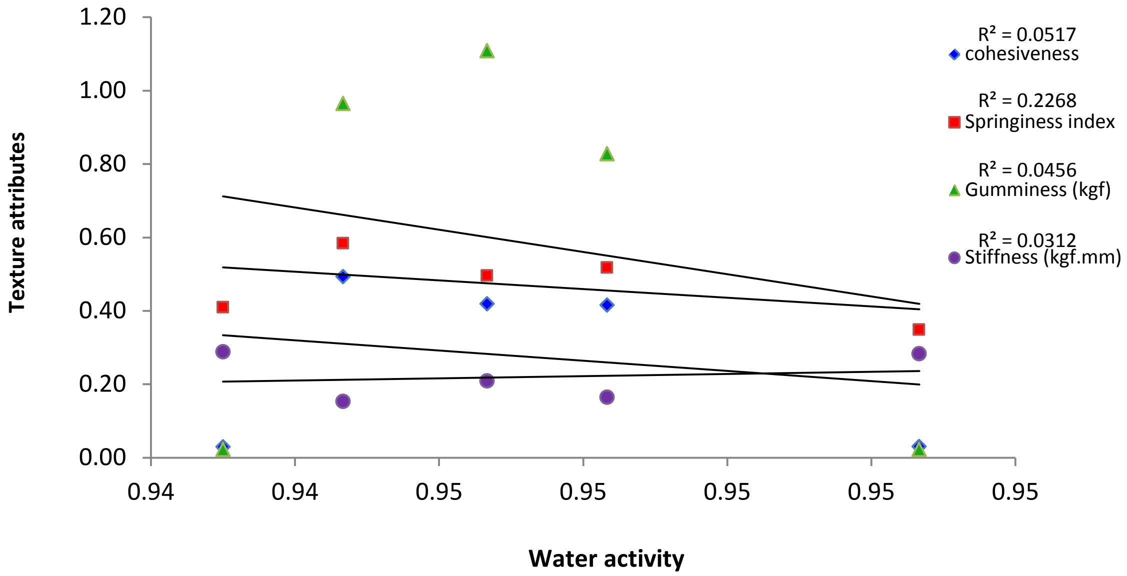

Figure 3 *Texture vs a_w of canned cheddar cheese stored at 30 °C for up to 730 days.*

3.2 Canned puddings

Three types of puddings were used in CRP: fruit; chocolate and golden; all were canned products with a semi-solid texture and were semi-moist product. Chocolate and golden puddings were self-saucing with a homogeneous matrix, whereas fruit pudding did not include a sauce and had a heterogeneous matrix consisting of a mixture of dried fruits dispersed throughout a cake base. No initial texture data was available for any of the three types.[1]

3.2.1 Fruit pudding

There were few significant changes in texture during storage (Table 4). There were decreases in cohesiveness during storage at 1°C and gumminess at 30 °C. The texture data for fruit pudding was subject to relatively large standard deviations (e.g. 0.40±0.17; 0.34±0.05) and weak texture-time relationships (R_2 range 0.01 to 0.53).

[1] based on the available data at the time the report was prepared.

Table 4 *Fruit pudding – texture changes (first to last storage point) during storage at 1, 20, 30, 40 and 50 °C.*

Texture attribute/temperature	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
Cohesiveness					
Springiness					
Gumminess					

Note:

		Highly significant increase/decrease (p<0.001)
		Significant increase/decrease (p<0.05)
		No significant difference (p>0.05)

3.2.2 Chocolate pudding

Texture measurements were consistent with low standard deviations for all attributes. There were clear declining trends for cohesiveness (R^2 0.97, 0.69) and gumminess (R^2 0.72, 0.65) at 20 °C and 30 °C respectively (Table 5). No significant changes were observed at 40 °C and 50 °C.

Table 5 *Chocolate pudding – texture changes during storage at 1, 20, 30, 40 and 50 °C.*

Texture attribute/temperature	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
Cohesiveness					
Springiness					
Gumminess					

Note:

		Highly significant increase/decrease (p<0.001)
		Significant increase/decrease (p<0.05)
		No significant difference (p>0.05)

3.2.3 Golden pudding

Data was quite consistent for all texture attributes, with small standard deviations (e.g. 0.44±0.013). There were significant and highly significant decreases in cohesiveness at 1, 20 and 30 °C (Table 6 and Figure 4). Springiness significantly decreased during storage at 1 °C and 20 °C, but increased highly significantly at 40 °C. Gumminess significantly decreased at 20 °C and 30 °C, with no significant changes observed at other storage temperatures. Significant changes were observed at 20 °C for all texture attributes, whereas not all attributes were significantly affected at higher temperatures, and none at 50 °C.

Table 6 Golden pudding – texture changes during storage at 1, 20, 30, 40 and 50 °C.

Texture attribute/temperature	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
Cohesiveness					
Springiness					
Gumminess					

Note:

		Highly significant increase/decrease ($p<0.001$)
		Significant increase/decrease ($p<0.05$)
		No significant difference ($p>0.05$)

The differences in composition were reflected in the reproducibility of texture measurements—the heterogeneous matrix had an inherently variable texture. Long term storage (20 °C and 30 °C) seemed to have a greater effect on texture than short term storage at high temperature (40 °C and 50 °C). Long term storage at 1°C also significantly affected the cohesiveness (fruit and golden pudding) and springiness (chocolate and golden pudding). Although no significant change was observed for springiness of golden pudding at 30°C, the charts (Figure 4) show a slightly decreasing trend.

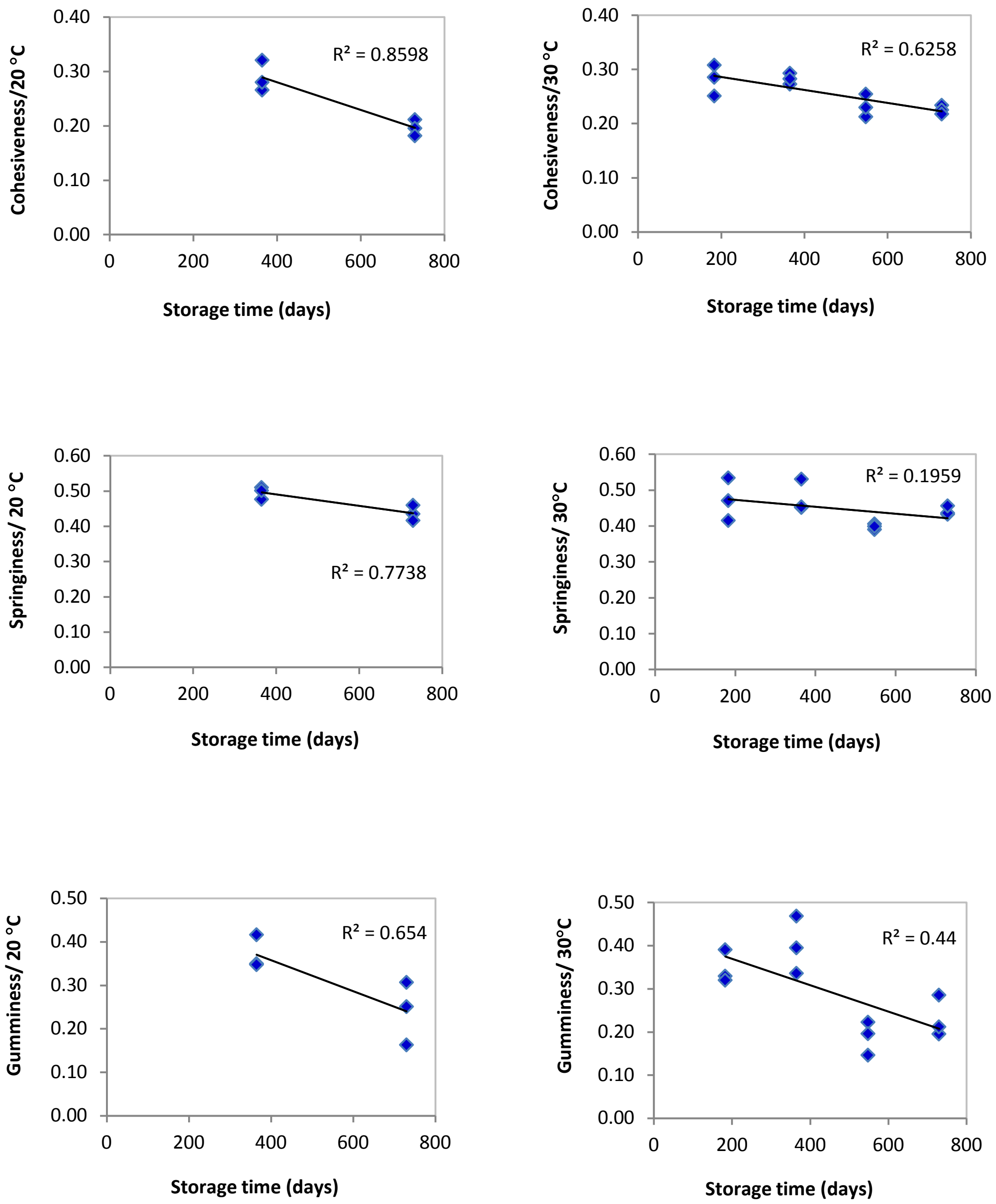

Figure 4 Texture attributes of golden pudding stored at 20 ℃ (left) and 30 ℃ (right) for up to 730 days.

3.2.4 Water activity of puddings

As all the puddings were canned products, protected from loss of moisture, there was little expectation of changes in texture or a_w. A summary of changes in a_w during storage for all puddings is shown in Table 7 (and Figures A1 to A3, Appendix A). Correlations between

texture and a_w have been presented for all puddings (Figure 5). Although the changes in a_w were minor, some were significant and correlated with changes in texture.

The a_w data had small standard deviations (e.g. 0.23±0.008) for all puddings. Most changes in a_w were at 50 °C (Table 7). Fruit pudding a_w did not change significantly during storage (first versus last point) at 1, 20, 30 and 40 °C, whereas there were some significant changes in a_w of chocolate and golden pudding during storage.

Table 7 Changes of aw of canned puddings stored at 1, 20, 30, 40 and 50 °C.

Products/storage conditions	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
Fruit pudding					
During storage (first vs last point)					
Initial vs first storage point					
Initial vs last storage point					
Chocolate pudding					
During storage (first vs last point)					
Initial vs first storage point					
Initial vs last storage point					
Golden pudding					
During storage (first vs last point)					
Initial vs first storage point					
Initial vs last storage point					

Note:

		Highly significant increase/decrease (p<0.001)
		Significant increase/decrease (p<0.05)
		No significant difference (p>0.05)

There may be some potential to set performance criteria for attributes of texture of golden and chocolate self-saucing puddings as these have been shown to change significantly during storage. An important consideration is whether the changes in texture were associated with changes in sensory acceptability. The texture of fruit pudding was less affected by storage, therefore there is no basis on which to consider attributes of texture as performance criteria.

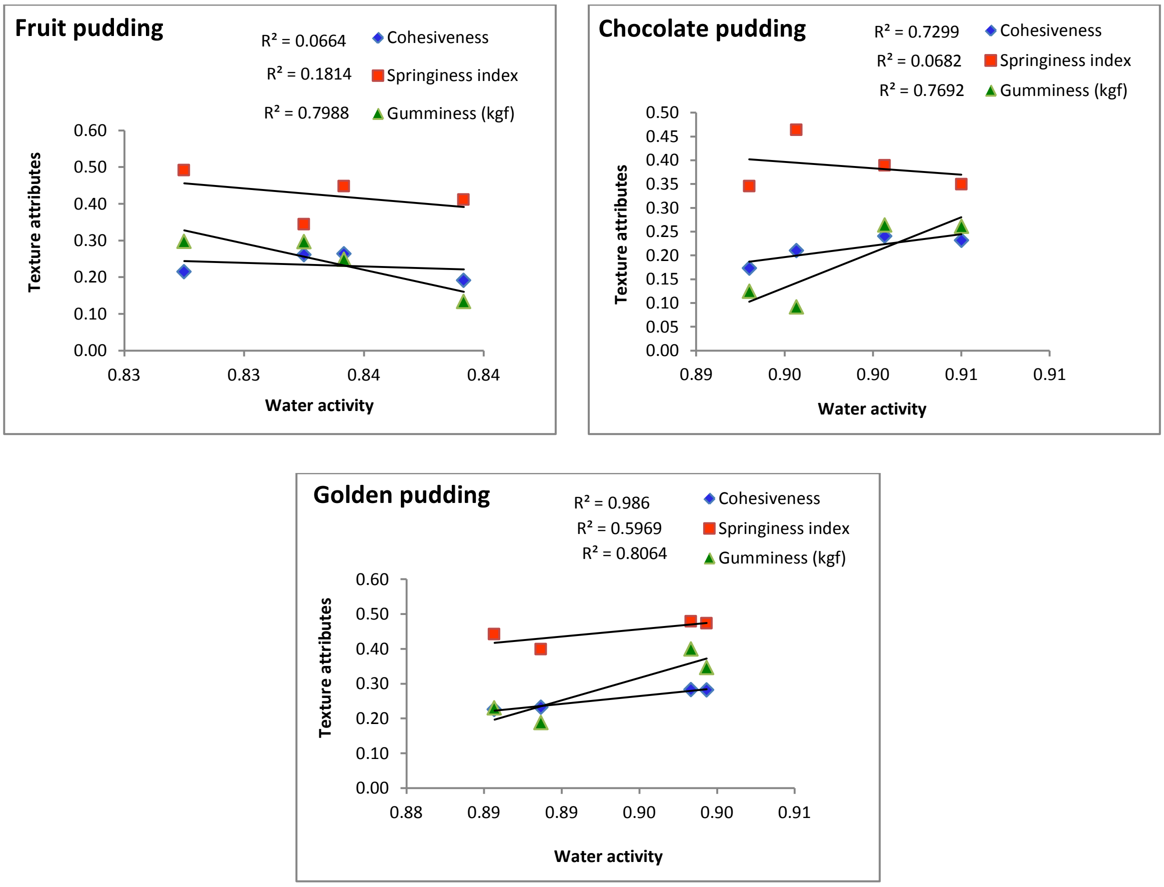

Figure 5   Texture vs a_w of canned puddings stored at 30 °C for up to 730 days.

3.3 Muesli Bar

The three muesli bars (apricot and coconut, tropical and forest fruits) all contained dried fruit and were chewy type bars. No initial texture data was available for any of these varieties.

3.3.1 Apricot & coconut muesli bar

No significant changes were observed during storage for texture attributes, except at 40 °C for break strength and deformation ($p<0.05$; R^2 0.64 and 0.46 respectively). In general, there were large standard deviations, e.g. break strength 3.47±3.72 (30 °C/730 days) and 1.25±1.27 (50 °C/84 days). There were significant changes in samples stored at 40 °C with increases in break strength and decreases in deformation (Table 8).

Table 8 Apricot & coconut muesli bar – texture changes during storage at 1, 20, 30, 40 and 50 °C.

Texture attribute/temperature	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
Break strength					
Deformation					

Note:

		Highly significant increase/decrease (p<0.001)
		Significant increase/decrease (p<0.05)
		No significant difference (p>0.05)

3.3.2 Forest fruit muesli bar

The data was quite variable for most time and temperature points, e.g. break strength at 30 °C was 2.04±3.06 (R^2 0.10). The only significant changes were for break strength at 40 and 50 °C; no significant changes were observed for other attributes or temperatures (Table 9).

Table 9 Forest fruit muesli bar – texture changes during storage at 1, 20, 30, 40 and 50 °C.

Texture attribute/temperature	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
Break strength					
Deformation					

Note:

		Highly significant increase/decrease (p<0.001)
		Significant increase/decrease (p<0.05)
		No significant difference (p>0.05)

3.3.3 Tropical muesli bar

Some samples stored at 1°C and 20 °C did not break when tested, but instead bent, limiting the collection of break strength data. In addition, large standard deviations were observed for all storage profiles, e.g. break strength at 50 °C/84 days was 0.46±0.34 (R^2 0.52). For these reasons, no real conclusions could be drawn. A highly significant decrease in break strength was observed for samples stored at 1 °C, and a significant increase in break strength for samples stored at 40 °C (Table 10).

Table 10 Tropical muesli bar – texture changes during storage at 1, 20, 30, 40 and 50 °C.

Texture attribute/temperature	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
Break strength					
Deformation					

Note:

		Highly significant increase/decrease (p<0.001)
		Significant increase/decrease (p<0.05)
		No significant difference (p>0.05)

In general, there were few changes in texture. There were significant increases in break strength at 40 °C for all three varieties. However, no real conclusions could be drawn for texture changes during storage due to the large variability in data.

3.3.4 Water activity of muesli bars

During storage of tropical muesli bar, break strength decreased (highly significantly) at 1 °C (Table 10), which coincided with a significant increase in a_w (Table 11). However, there was no correlation between a_w and texture changes (Figure 7). Break strength of apricot and coconut muesli bar was weakly correlated with a_w (R^2 0.65).

High storage temperatures significantly decreased a_w levels in all muesli bars. In contrast, long-term storage at low temperatures (1°C and 20°C) increased a_w levels in all muesli bars significantly (Table 11 and Figures A4 to A6, Appendix A). This indicated that, over time, samples lost moisture at high storage temperatures (30, 40 and 50 °C) and gained moisture at lower storage temperatures (1 °C and 20 °C), suggesting package integrity may be compromised.[1]

Deformation data did not correlate with a_w (Figure 6).

Table 11 *Changes of a_w of muesli bars storage at 1, 20, 30, 40 and 50 °C/730 days.*

Products/storage conditions	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
Apricot & coconut muesli bar					
During storage (first vs last point)					
Initial vs first storage point					
Initial vs last storage point					
Forest fruit muesli bar					
During storage (first vs last point)					
Initial vs first storage point					
Initial vs last storage point					
Tropical muesli bar					
During storage (first vs last point)					
Initial vs first storage point					
Initial vs last storage point					

Note:

		Highly significant increase/decrease ($p<0.001$)
		Significant increase/decrease ($p<0.05$)
		No significant difference ($p>0.05$)

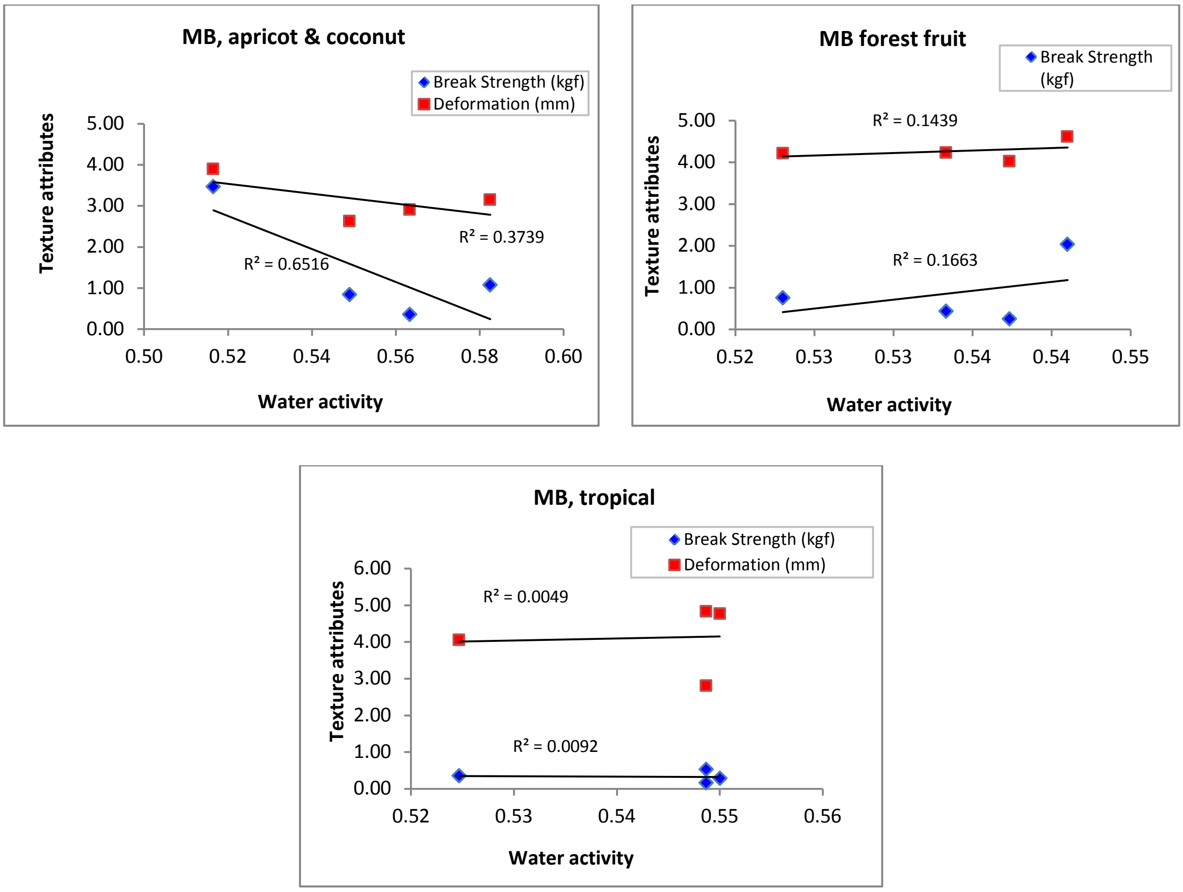

Figure 6 Texture attribute (break strength and deformation) vs a_w of muesli bars storage at 30 °C for up to 730 days.

3.4 Biscuits

In the 2009/10 testing regime there were four biscuits—two savoury (cream cracker and crispbread biscuits) and two sweet (butter and plain sweet biscuits). The biscuits varied in their compositions, fat content (from 7% to 22%) and processing conditions.

3.4.1 Cream cracker biscuit

Cream cracker biscuit was a leavened, baked biscuit with a light airy structure.

During storage, there were significant changes in break strength for samples stored at 20 and 30 °C and in deformation at 1 °C (Table 12). Initially both break strength and deformation are quite low compared to values obtained during storage, leading to significant differences between the initial and both first and final storage points. The general trend was for an increase from initial break strength and deformation values followed by a flattening out over time.

Table 12 Cream cracker biscuit – texture changes during storage at 1, 20, 30, 40 and 50 °C

Texture attribute/temperature	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
During storage (first vs last point)					
Break strength					
Deformation					
Initial vs first storage point					
Break strength					
Deformation					
Initial vs last storage point					
Break strength					
Deformation					

Note:

		Highly significant increase/decrease (p<0.001)
		Significant increase/decrease (p<0.05)
		No significant difference (p>0.05)

3.4.2 Crispbread biscuit

Crispbread biscuit is a hard baked, thin dry biscuit, containing many seeds and grains. The texture change observed in crispbread during storage was similar to those observed for cream crackers, but differed more from the initial values (Table 13).

Table 13 Crispbread biscuit– texture changes during storage at 1, 20, 30, 40 and 50 °C

Texture attribute/temperature	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
During storage (first vs last point)					
Break strength					
Deformation					
Initial vs first storage point					
Break strength					
Deformation					
Initial vs last storage point					
Break strength					
Deformation					

Note:

		Highly significant increase/decrease (p<0.001)
		Significant increase/decrease (p<0.05)
		No significant difference (p>0.05)

3.4.3 Butter biscuit

Butter biscuit is a shortbread sweet biscuit with a crumbly texture.

The most significant changes in texture during storage were observed in samples stored at 50 °C (Table 14). Break strength was also affected significantly at 20 and 30 °C. No significant changes in deformation were observed for samples stored at 20, 30 and 40 °C.

On the other hand, when comparing initial texture values to the first and last storage points, deformation showed highly significant increases at most temperatures, whereas break strength was only affected at 20 and 50 °C (Table 14, initial vs first and last storage points).

Table 14 Butter biscuit – texture changes during storage at 1, 20, 30, 40 and 50 °C

Texture attribute/temperature	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
During storage (first vs last point)					
Break strength					
Deformation					
Initial vs first storage point					
Break strength					
Deformation					
Initial vs last storage point					
Break strength					
Deformation					

Note:

		Highly significant increase/decrease (p<0.001)
		Significant increase/decrease (p<0.05)
		No significant difference (p>0.05)

3.4.4 Plain sweet biscuits

Plain sweet biscuit was a thin, rectangular shaped biscuit, coconut flavoured with a scattering of sugar crystals on the surface.

The results demonstrated some highly significant decreases in break strength during storage at 20 and 50 °C, and highly significant increases in deformation at all storage temperatures except 40 °C (Table 15). Similar to the butter biscuit, when compared to the initial value, the most significant change in texture was deformation.

Table 15 Plain sweet biscuit – texture changes during storage at 1, 20, 30, 40 and 50 °C

Texture attribute/temperature	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
During storage (first vs last point)					
Break strength					
Deformation					
Initial vs first storage point					
Break strength					
Deformation					
Initial vs last storage point					
Break strength					
Deformation					

Note:

		Highly significant increase/decrease ($p<0.001$)
		Significant increase/decrease ($p<0.05$)
		No significant difference ($p>0.05$)

3.4.5 Water activity of biscuits

Water activity significantly increased during storage for all biscuits, especially cream cracker and plain sweet biscuits (Table 16 and Figures A7 to A10, Appendix A). High storage temperature (50 °C) did not affect the a_w of crispbread and butter biscuits during storage. There were highly significant decreases in a_w for all biscuits stored at 40 °C.

Table 16 Summary of a_w of biscuits stored at 1, 20, 30, 40 and 50 °C

Products/storage conditions	**Storage temperature (°C)**				
	1	**20**	**30**	**40**	**50**
Cream cracker biscuit					
During storage (first vs last point)					
Initial vs first storage point					
Initial vs last storage point					
Cripsbread biscuit					
During storage (first vs last point)					
Initial vs first storage point					
Initial vs last storage point					
Butter biscuit					
During storage (first vs last point)					
Initial vs first storage point					
Initial vs last storage point					
Plain sweet biscuit					
During storage (first vs last point)					
Initial vs first storage point					
Initial vs last storage point					

Note:

		Highly significant increase/decrease ($p<0.001$)
		Significant increase/decrease ($p<0.05$)
		No significant difference ($p>0.05$)

Although deformation data demonstrated some significant changes during storage (Tables 12–15) and significant a_w changes at all temperatures, there was only one instance—butter biscuit—where there was evidence of a relationship between deformation and a_w (Figure 7).

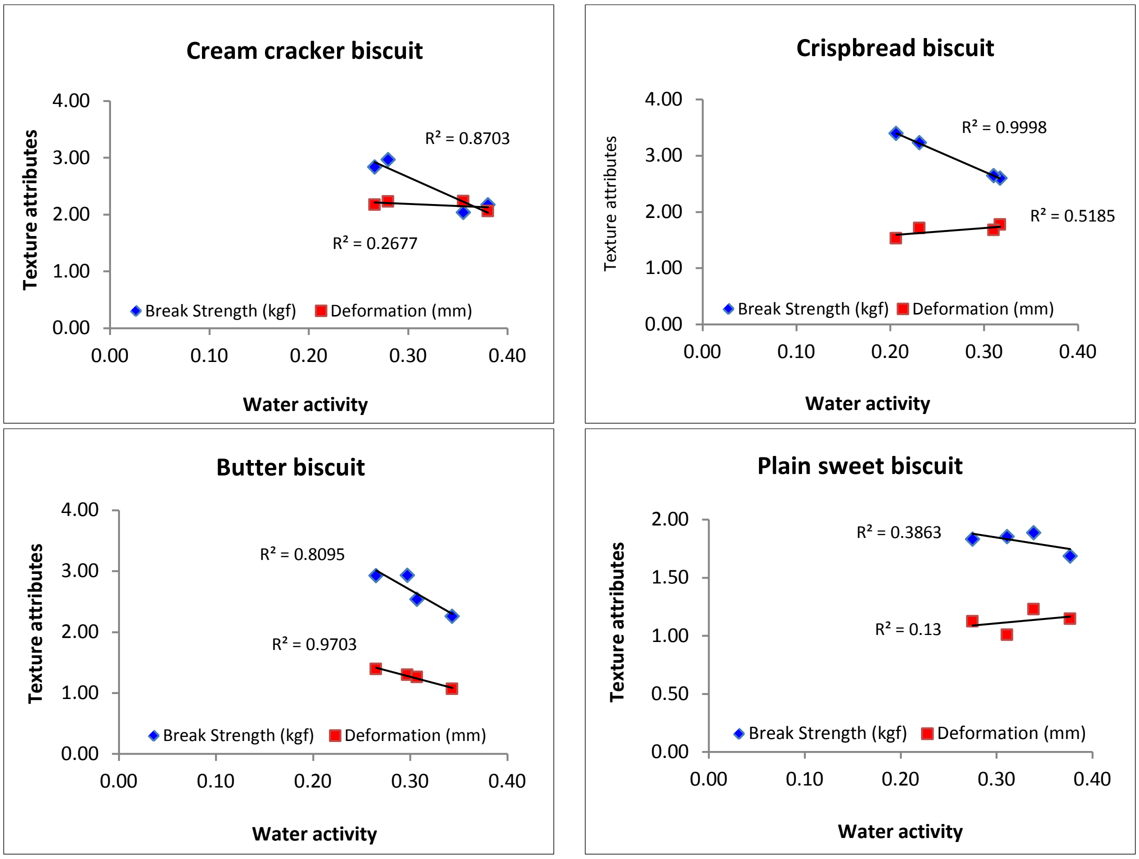

Figure 7 Texture attribute (break strength and deformation) vs a_w of biscuits stored at 30 ℃ for up to 730 days

There was a good correlation between break strength and a_w of all biscuits except plain sweet biscuit, i.e. break strength decreased as a_w increased (Tables 12 and 16 and Figure 7). The correlation between break strength and a_w suggested the possibility of using a_w as an indicator of textural quality. The a_w values may also be useful as a guide to susceptibility to deteriorative reactions such as non-enzymatic browning and fat oxidation during storage.

3.5 Issues and Opportunities

In general, the texture measurements examined for this report had large standard deviations. This presents difficulty in setting performance criteria and limits their usefulness as performance indicators. There may be opportunities to reduce the uncertainty associated with the texture measurements.

Approaches to improve the TPA procedure, and reduce uncertainty, may include consideration of:

- The use of standard methods of testing, reference materials and controlled environmental conditions.
- The dimensions, shape and structure of samples. For example, isotropic foods can be tested in any orientation while anisotropic foods should always be aligned in the same direction.
- The number of replicates analysed – homogeneous food matrices requires fewer replicates than heterogeneous matrices.

Despite the large measurement uncertainties, it is clear that there were some significant changes in texture during storage.

- Most texture attributes of canned cheddar cheese changed significantly for most temperatures from the initial values to those at the first storage point, with the differences becoming more significant as storage progressed. This includes the changes observed for samples stored at 1°C, suggesting that either these samples do not serve as good controls for initial conditions or there were some significant changes in analytical conditions (e.g. instrument, environment, protocols).
- The texture of golden and chocolate self-saucing puddings changed significantly during storage. An important consideration is whether the changes in texture are associated with changes in sensory acceptability. The texture of fruit pudding did not change as much as the other pudding types, therefore the texture of this type of pudding would serve no purpose as an indicator of product deterioration.
- There were some significant changes in the deformation of biscuits during storage and there were significant changes in a_w at all temperatures. In the case of butter biscuit there was evidence of a correlation between deformation and a_w. Potentially, either texture or a_w measurements could be used as an indicator of quality changes during storage.
- There was a good correlation between break strength and a_w of all biscuits except plain sweet, i.e. break strength decreased as a_w increased. This suggests the possibility of using a_w as an indicator of textural quality. The a_w values may also be useful as a guide to susceptibility to deteriorative reactions such as non-enzymatic browning and fat oxidation during storage.

The a_w data examined in the preparation of this report had small standard deviations. Where changes in texture correlate with changes in a_w, there may be opportunities to establish performance criteria based on a_w, an easier and cheaper measurement to make.

The usefulness of TPA and a_w measurements in the establishment of performance criteria is largely reliant upon there being a recognised and measureable relationship between these measurements and sensory quality. It is important to understand the correlation between TPA and sensory evaluation data to determine the TPA values at which sensory texture is no longer acceptable. A study designed to elicit this information would be required before performance criteria based on TPA measurements could be set.

4. Conclusions

1. TPA measurements typically have large standard deviations and are not currently suitable for the setting of performance criteria.
2. As some significant changes in texture during storage were observed, efforts should be made to either reduce the uncertainty associated with these measurements or establish a suitable surrogate measure. Some approaches that may improve TPA were discussed.
3. Significant changes in texture were observed for golden and chocolate self-saucing puddings and biscuits. Potentially, performance criteria based on TPA could be established for these types of food.
4. Changes in some texture attributes correlated with changes in a_w, the uncertainty associated with the a_w data was small, and the method is easier and cheaper than TPA to undertake. In such cases, there is potential to use a_w instead of TPA as a measure of textural quality.
5. The correlation between TPA measurements and sensory evaluation data has not been investigated, therefore the establishment of TPA criteria that have been validated against sensory texture data not yet possible.

5. Recommendations

1. Where there is evidence that TPA measurements may be useful as performance criteria, it would be useful to investigate means to reduce the uncertainty associated with the TPA measurements, implement improvements and establish suitable criteria. Efforts to establish texture-based performance criteria should focus initially on golden and chocolate self-saucing puddings and biscuits.
2. Investigate the potential to use a_w instead of TPA as a measure of textural quality. Efforts to establish performance criteria based on a_w as a surrogate for TPA measurements should focus initially on biscuits.
3. Determine the correlation between TPA measurements and sensory evaluation data, including relevant attributes and the range of TPA values at which sensory texture is not acceptable.

6. Acknowledgements

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Appendix A: Water activity of food components

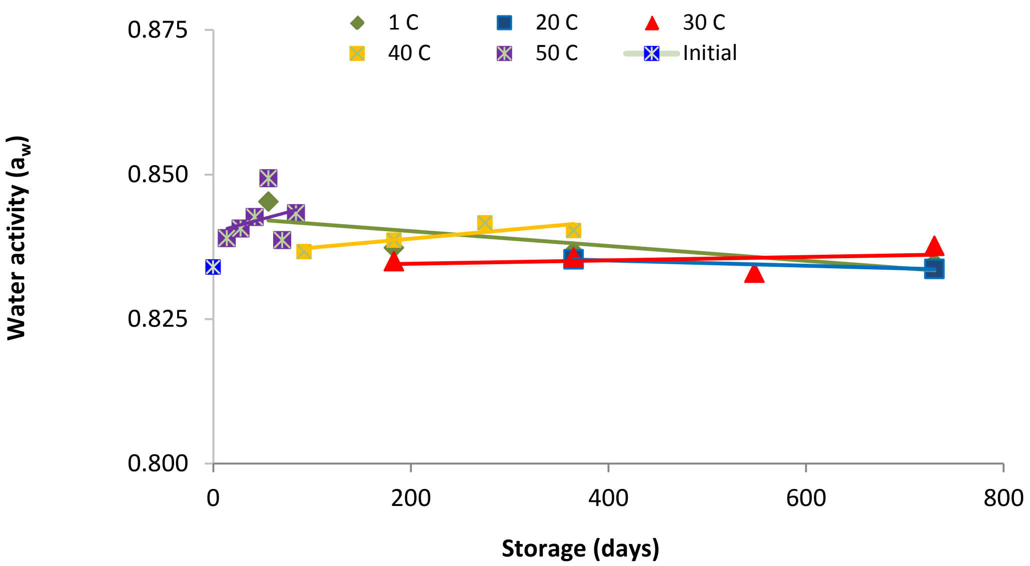

Figure A1 Water activity of fruit puddings stored at 1, 20, 30, 40 and 50 ℃ for up to 730 days.

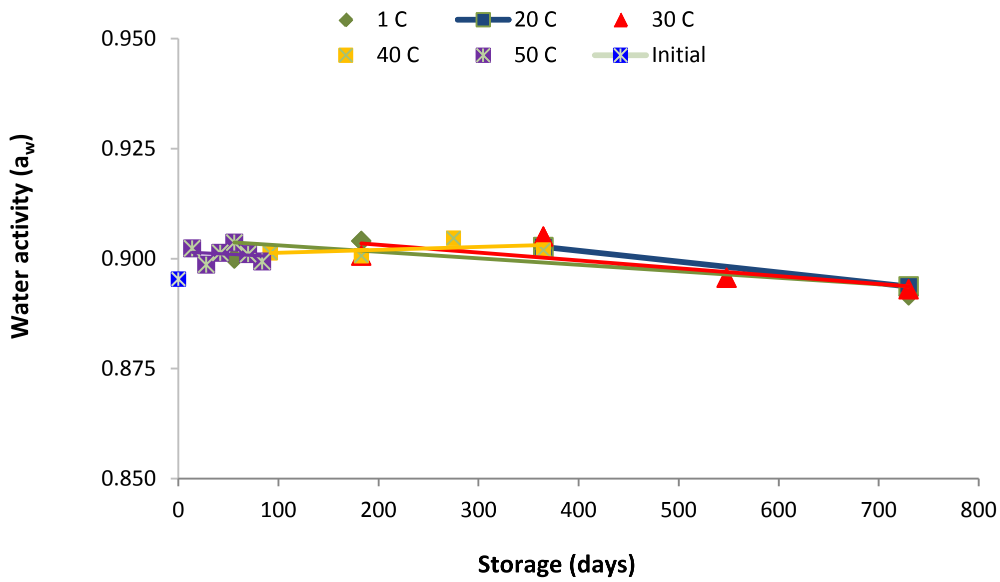

Figure A2 Water activity of chocolate puddings stored at 1, 20, 30, 40 and 50 ℃ for up to 730 days.

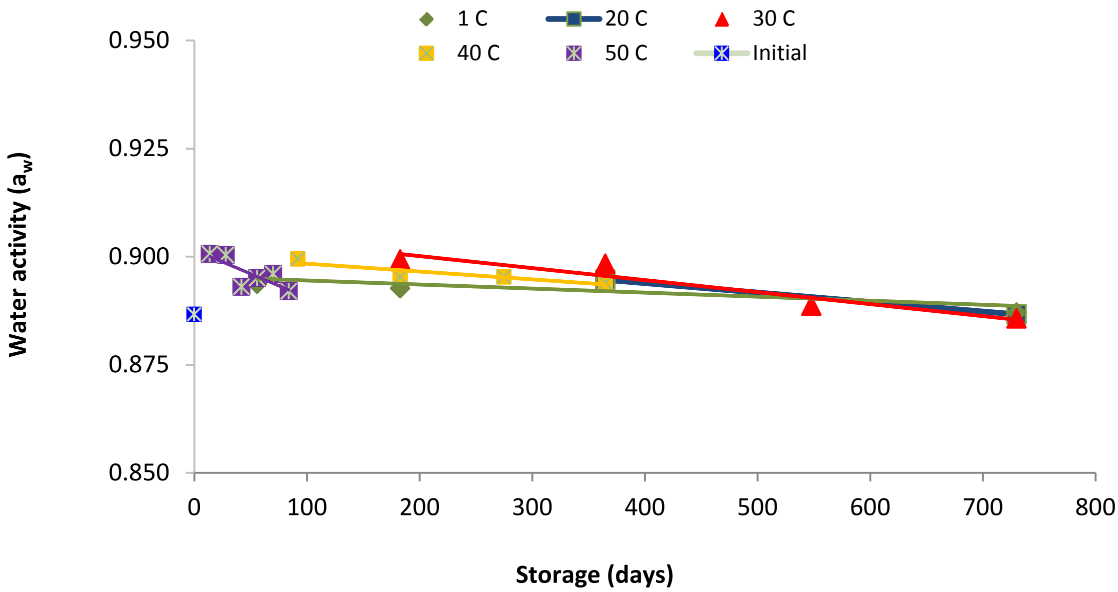

Figure A3 *Water activity of golden puddings stored at 1, 20, 30, 40 and 50℃ for up to 730 days.*

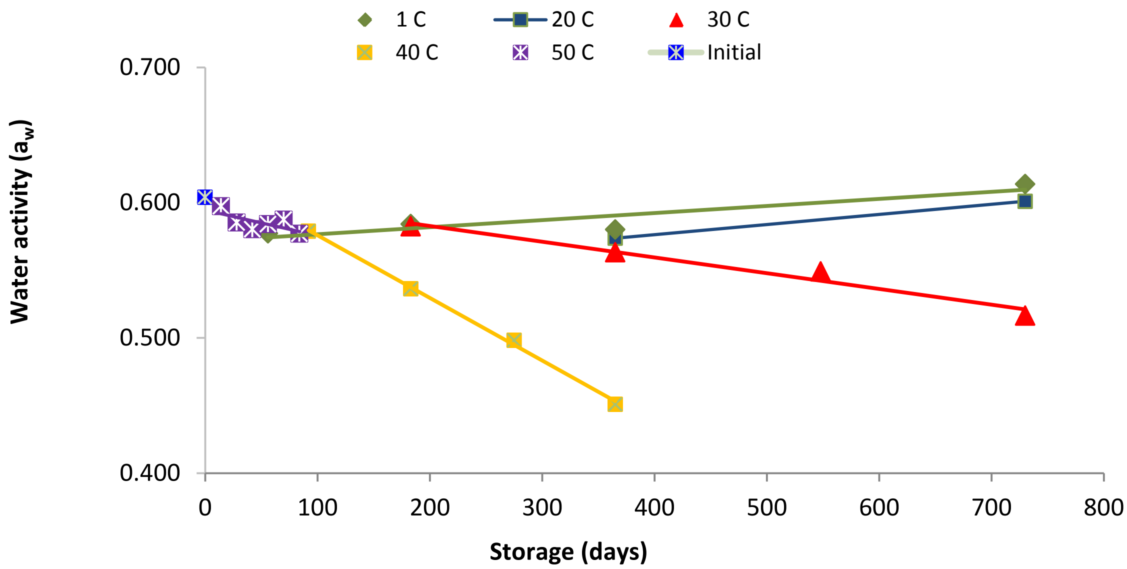

Figure A4 *Water activity of muesli bar, apricot & coconut stored at 1, 20, 30, 40 and 50℃ for up to 730 days.*

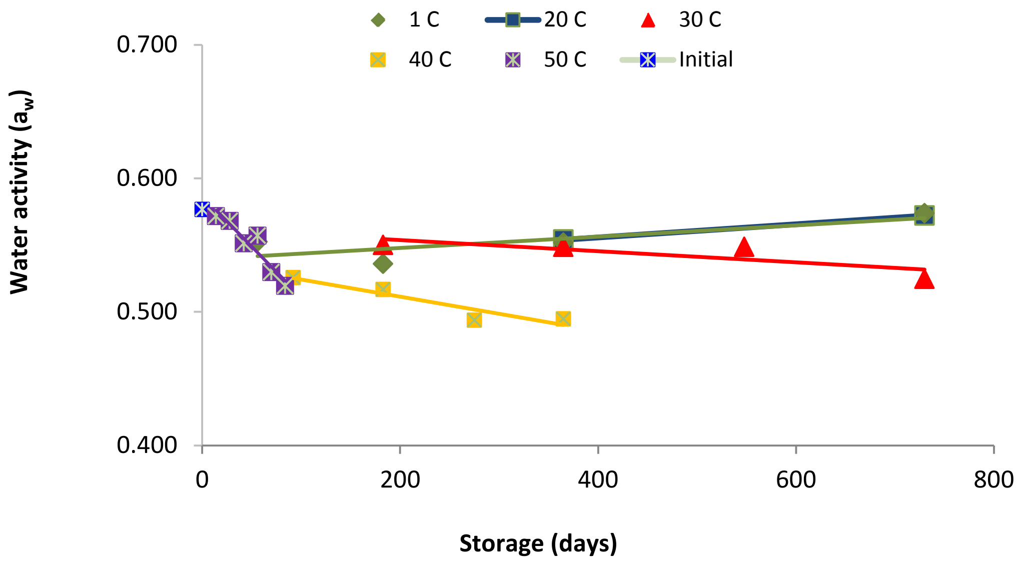

Figure A5 *Water activity of muesli bar, tropical stored at 1, 20, 30, 40 and 50 ℃ for up to 730 days.*

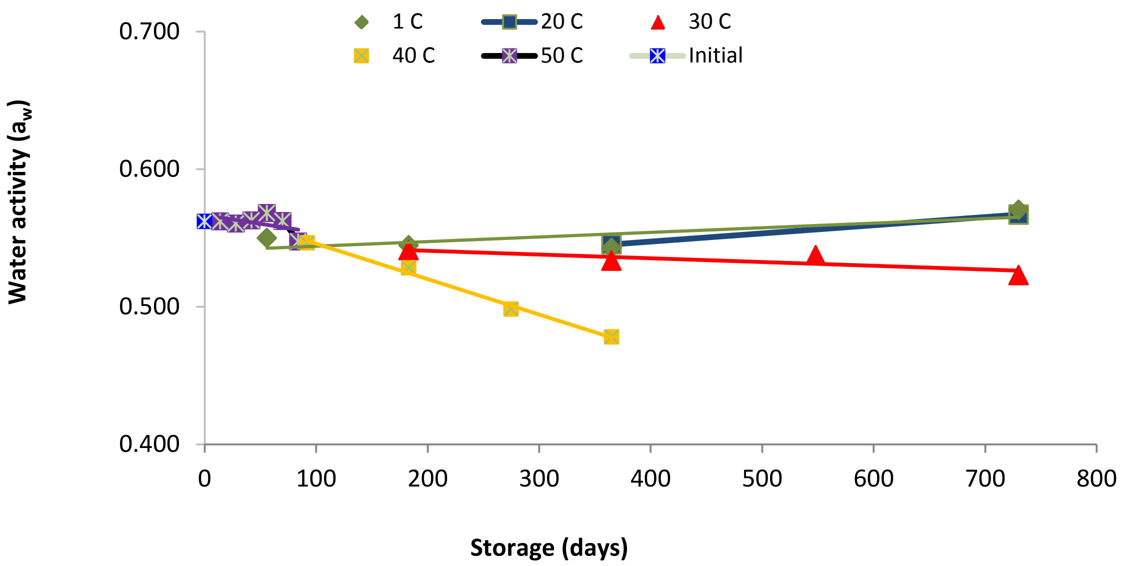

Figure A6 *Water activity of muesli bar, forest fruits stored at 1, 20, 30, 40 and 50 ℃ for up to 730 days.*

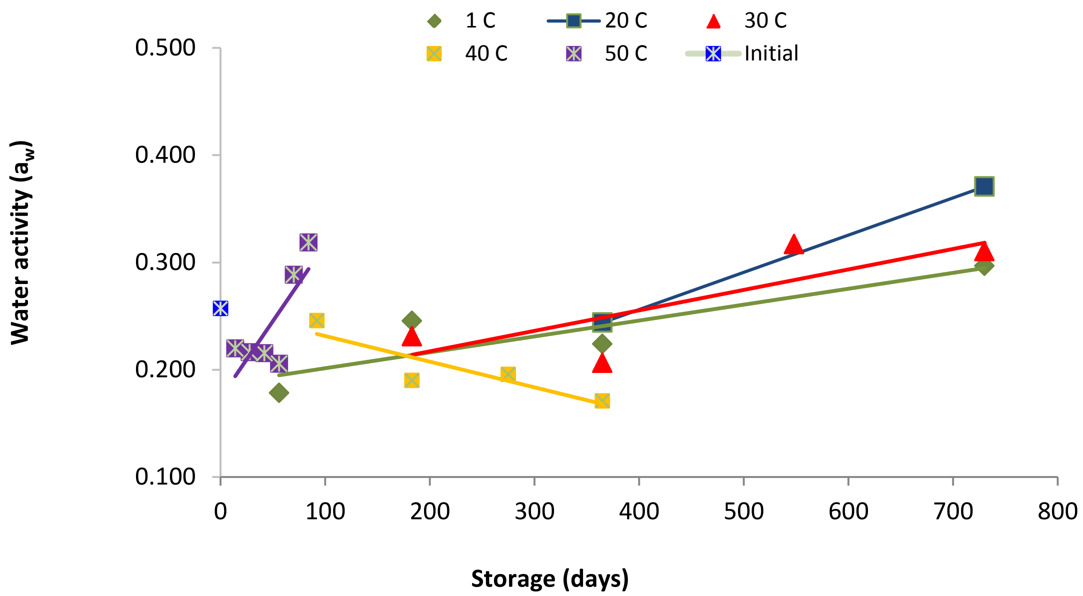

Figure A7 *Water activity of cripsbread biscuits stored at 1, 20, 30, 40 and 50 ℃ for up to 730 days.*

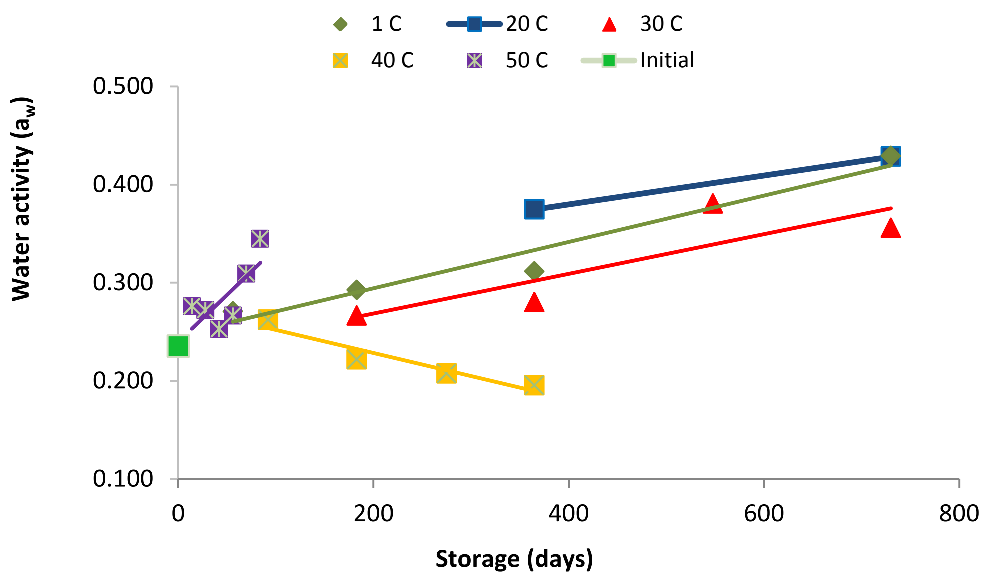

Figure A8 *Water activity of cream cracker biscuits stored at 1, 20, 30, 40 and 50 ℃ for up to 730 days.*

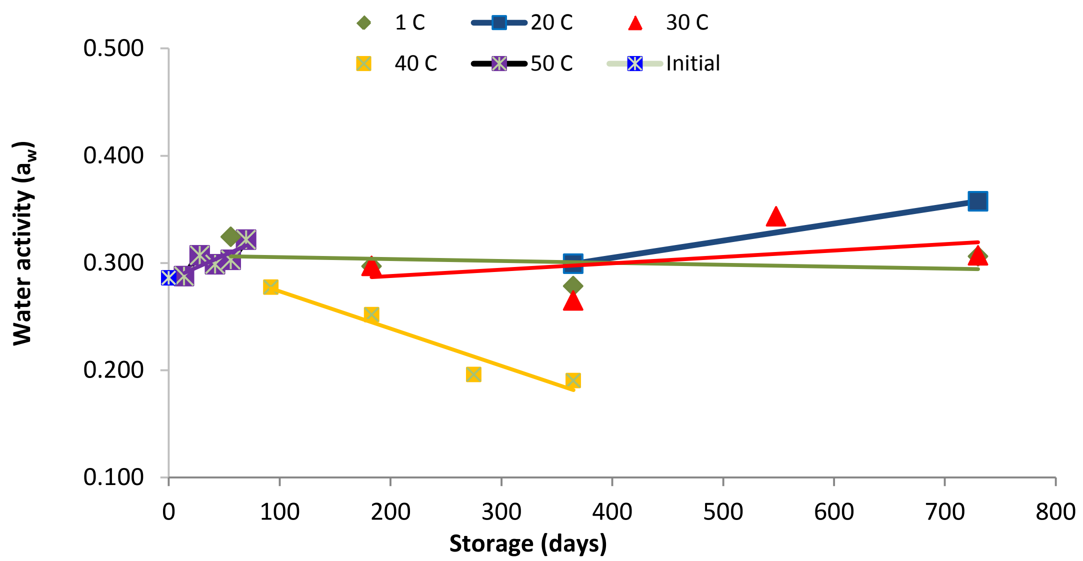

Figure A9 *Water activity of butter biscuits stored at 1, 20, 30, 40 and 50 ℃ for up to 730 days.*

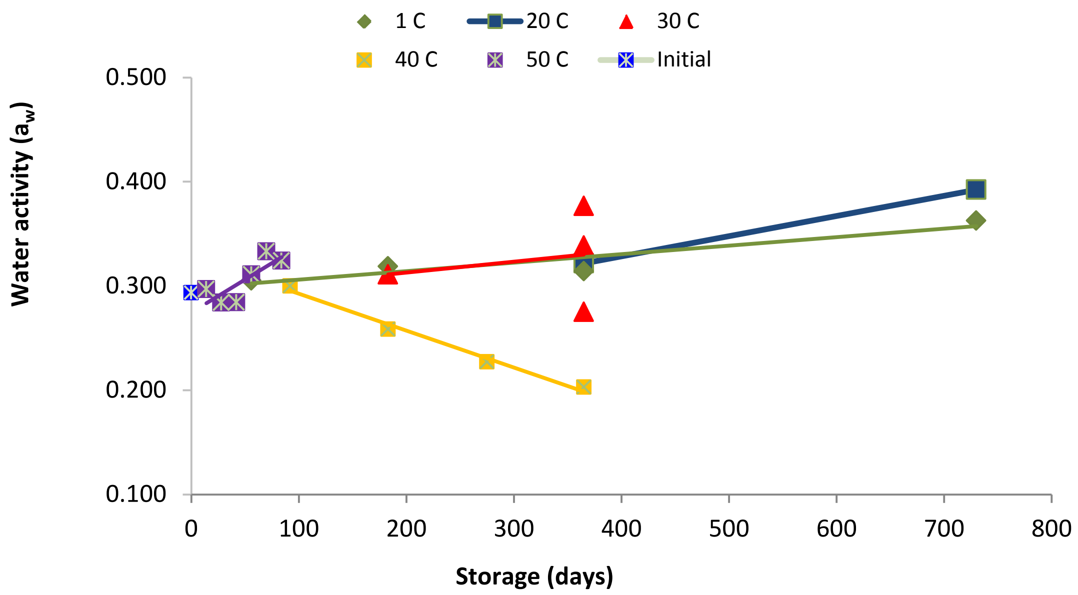

Figure A10 *Water activity of plain sweet biscuits stored at 1, 20, 30, 40 and 50 ℃ for up to 730 days.*

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19. ABSTRACT

DEF(AUST) specifications for combat ration pack (CRP) food components include functional and performance criteria to ensure that components that are procured are suitable for their intended purpose. Texture profile analysis (TPA) and water activity (a_w) data have been reviewed to assist in the establishment of performance criteria for CRP food components. The texture measurements displayed large standard deviations limiting their usefulness as performance indicators. In contrast, the uncertainty associated with the a_w data was very low. It is suggested that a_w be used instead of TPA as a measure of textural quality and stability. An understanding of the correlation between TPA and sensory evaluation data would then be required to establish performance criteria based on TPA.